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ABSTRACT

This study consolidated observations of teachers in an institute setting designed to facilitate science learning content through performing science processes and asking questions related to self-perceived conceptual difficulties. The subjects were 11 elementary school teachers from a school district in Northeast Florida; they were enrolled in a two-week elementary science institute during the summer of 1988. The school district required that a number of physical science concepts, including density, be included in the instructional sequence. After an introduction to basic and integrated science processes, the teachers completed a 13-item, two-tiered density inventory. A two-day treatment which focused on misconceptions identified on the pre-test followed; the instructors used strategies designed to encourage and promote teachers' question-asking behavior. Post-test results showed that several teachers corrected many of their misconceptions. However, some teachers either adhered to original misconceptions or changed original answers by giving a new incorrect response or replacing a pre-test correct response with a post-test incorrect response. In both cases, teachers required further remediation to completely remove misconceptions. (Author/CW)

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OBSERVATIONS RELATED TO TEACHER CONCEPT FORMATION IN AN IN-SERVICE SETTING EMPHASIZING QUESTION-ASKING BEHAVIOR

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ABSTRACT

This study consolidates a number of observations of teachers in an institute setting designed to facilitate learning content through performing science processes and asking questions related to self-perceived conceptual difficulties. The subjects were eleven elementary school teachers from a school district in Northeast Florida; they were enrolled in a two-week elementary science institute during the summer of 1988. The school district required that a number of physical science concepts, including density, be included in the instructional sequence. After an introduction to basic and integrated science processes, the teachers completed a thirteen item, two-tiered density inventory. A two-day treatment which focused on misconceptions identified on the pre-test followed; the instructors used strategies designed to encourage and promote teachers' question asking behavior.

Pre-test results yielded the following error patterns:

(1) confusion of mass and volume of solids and liquids;
(2) confusion of mass and density of solids and liquids;
(3) inability to conceptualize gases with characteristics of mass and density;
(4) difficulty in conceptualizing more gas particles in a given space;
(5) difficulty in performing density problem calculations.

Post-test results showed that several teachers corrected many of their misconceptions. However, some teachers either (1) adhered to original misconceptions or (2) changed original answers by giving a new incorrect response or replacing a pre-test correct response with a post-test incorrect response. In both cases, teachers required further remediation to completely remove misconceptions.

Qualitative observations during the treatment period were that the teachers tended to increase the number of questions which they asked and that they became more skillful at question-asking, especially in forming questions which led to productive action which facilitated removal of misconceptions.

Purpose:

During the past five years, the State of Florida, reflecting nationwide concern about teaching quality, has supported two-week intensive summer in-service institutes for teachers at district levels in a number of subject areas, including elementary science. The legislative rule required that the institutes be rigorous in content, implying that stronger teacher content background will ultimately improve student content knowledge. However, many elementary teachers enter the institute settings with a continuing fear of science and with science misconceptions. This study consolidates a number of observations of teachers in a particular institute setting designed to facilitate learning content through doing science processes and asking questions related to self-perceived conceptual difficulties. Qualitative findings are discussed and related to quantitative results gathered by administering a two-tiered instrument designed to assess density concept attainment.

Theoretical Base:

Research in the cognitive sciences has led science educators deeper into the intricacies of concept formation, including the area of misconceptions. Constructivists, using schema theory first introduced by Bartlett in 1932 (Cohen, Eyesenck, & LeVoi, 1986), have gathered data and built learning models related to student thinking in science (Osborne & Wittrock, 1985; Driver and Bell, 1986). These models describe learning as a generative process which requires periodic letting go of tenacious conceptual errors before concepts can be integrated meaningfully into memory systems. This process should, ideally, be facilitated by a teacher who can function as a learning mediator and enhancer by helping students to focus on their own questions about phenomena (Barnes, 1988). Facilitative teachers should be skilled in pre-assessment techniques, such as designing and using instruments similar to those of the two-tiered variety which indicate both answers to propositional statements and reasons for those answers (Halsam & Treagust, 1987). Teachers should also be able to track qualitative changes in learner concept formation according to criteria of intelligibility, plausibility, and fruitfulness (Braathen & Hewson, 1988).

However, after extensive interactions with elementary teachers in in-service settings, the investigators have inferred that most teachers are not able to delve into problems associated with student concept formation without several opportunities to wrestle with their own idiosyncratic conceptual schemes. Didactic approaches provide no obvious opportunity for the teacher to engage in the level of questioning needed to confront his/her own misconceptions and reorganize cognitive structures to align with currently accepted scientific thought.

This study describes an in-service approach which attempts to foster question-asking behavior as a vehicle for teachers' confronting their own misconceptions. The topic of density was the focus for collecting qualitative and quantitative data.

Procedure:

The subjects in the study were 11 elementary school teachers from a school district in northeast Florida enrolled in an elementary science institute, Summer 1988. The institute component required that a number of physical science concepts be covered including that of density. After an introduction to basic and integrated science processes, especially observation, inference, prediction, and the nature of scientific questioning, the teachers completed a 13 item, two-tiered density inventory (Betkouski & McDonald, 1986). Eleven items on the inventory required a true-false answer and a choice of one of four reasons for the answer. The reasons were constructed so that all but the correct response reflected commonly held misconceptions about density and its subordinate concepts of mass and volume. The teachers scored their own tests and became aware of their personal difficulties with aspects of density.

A two-day treatment (3 hours per day) followed and focused on misconceptions evident on the pre-test by means of strategies to encourage and promote teachers' question asking behavior. Simple materials were used and attention was directed to topics of balance, mass, volume, prediction, data collection and analysis, and explaining relationships of mass, volume, and density in solids, liquids, and gases.

In a study of questioning behavior of young children in a science setting, Barnes (1988) notes that the following teacher strategies tend to enhance student questioning behavior:

(1) presenting familiar and unfamiliar objects and/or materials to the child;
(2) helping the child to focus, especially by asking the child to ask questions about the object or situation;
(3) modeling questioning behavior for the child.
Children demonstrated increased output of questions, increased skill at asking questions which led to productive action, and were more likely to express some understanding of the importance of questioning in science. With these experiences in mind, the treatment was designed to build for the institute participant a learning environment which reflected similar strategies, i.e., material based, instructor modelling, and the encouraging and expecting of question asking behavior on the part of the teacher participants. The approach was to treat the teachers as colleagues with a view toward creating a trusting, supportive, non-judgmental setting where participants could gain confidence in question asking, admit to ignorance and confusion about specific ideas and concepts in a non-threatening setting, and interact with materials and phenomena in order to challenge their own concepts.

Particular instructor behaviors included:
(1) providing materials and requesting teachers to provide other materials pertinent to individual investigation;
(2) asking questions of teachers during demonstrations and individual investigations, e.g., "What will happen if --- ?", "How do you support your conclusion?", "How can you test this notion?"
(3) asking teachers to verbalize and write out their questions and to pursue methods to find out answers;
(4) asking teachers to ask questions of each other and to present data and interpretations to one another (cooperative group work);
(5) presenting data and asking teachers to generate their own data;
(6) giving each teacher opportunities to talk aloud their questions, their actions, and their changing perceptions.

Qualitative Results:

The researchers kept and discussed anecdotal records of participant behavior and class interaction patterns before, during and after the treatment. The small class size and a healthy class rapport permitted each participant to actively engage in

instructional activities. Teachers in the study tended to respond as do young children. Their behavior was as follows:
(1) the frequency of questions increased as the treatment progressed;
(2) the teachers became more skillful at question asking, especially in formulating questions which lead to productive action, e.g., "What will happen to the density if I keep the mass the same and increase the volume?"
(3) the teachers appeared to develop confidence in their own ability to challenge their understanding/explanation of phenomena, e.g., they developed their own individual investigations beyond activities planned and presented by the instructors.

Quantitative Results:

Pre-test results (similar to pre-tests results of another elementary science institute group of 19 teachers during Summer 1988) yielded the following error patterns:
(1) confusion of mass and volume of solids and liquids;
(2) confusion of mass and density of solids and liquids;
(3) inability to conceptualize gases with characteristics of mass and density;
(4) difficulties in conceptualizing more gas particles in a given space;
(5) difficulties in performing density problem calculations.

All questions with the exception of question * 9 (missed by 5 teachers) were missed by over half of the participants. Question * 9 displayed two boxes, one with ten gas particles and another, half its volume, with five gas particles. The item asked whether the gas in the first situation had more mass than the gas in the second situation.

Post-test results showed significant improvement. Only three questions (*5,6 & 8) were missed by more than half the teachers. Numbers 5 and 6 relate to liquids and number 8 deals with density of a gas. Although several teachers corrected misconceptions, some (1) adhered to original misconceptions or (2) changed original answers by giving a new incorrect response or replacing a pre-test correct response with a post-test incorrect response.

The density inventory items which are of a two-tiered variety are numbers 1-10 and 13. A profile of teacher errors was

constructed by assuming that each item had potential for two kinds of errors, a true-false decision error and a multiple-choice support error. Table I summarizes total, decision, and support errors made by each teacher on the pre and post-test. The mean number of errors on the pre-test was 10.9, reduced to 5.82 on the post-test. There were more than twice the number of support errors as there were decision errors on the pre-test, indicating that a right answer was often chosen with an incorrect reason.

-insert Table I about here-

An analysis of each item is displayed in Table II. Each item is listed with the number of teachers making any error on the item, the number of total errors (decision plus support errors) on each item, the number of decision errors and the number of support errors for both pre- and post-tests. Table III summarizes the error patterns for each item.

-insert Tables II and III about here-

Conclusions:

The question asking format of the institute was successful in that it succeeded in having teachers confront many of their own misconceptions. Affectively, the teacher response was highly positive as scored on the final institute evaluations. Teacher comments indicated that they saw themselves as successful, active learners who benefitted from question asking strategies and planned to use them in their own classrooms.

In-service planning should include cognizance of the time required to fully remediate certain science misconceptions. A number of teachers substituted new errors for original ones as they sought to consolidate ideas about aspects of density. The institute instructors found it useful to discuss the post-test and then further treat especially troublesome areas. This additional step suggests that teachers, too, find it difficult to let go of misconceptions and need to be monitored even beyond well-designed treatments as they attempt to make concepts intelligible, plausible and fruitful.

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TABLE I
ERRORS BY TEACHERS ON DENSITY INVENTORY: ITEMS 1-10 & 13

TCH	PRE TOTAL	PRE DECISION	PRE SUPPORT	POST TOTAL	POST DECISION	POST SUPPORT
1	13	4	9	2	0	2
2	8	1	7	7	3	4
3	13	5	8	5	2	3
4	13	5	8	3	1	2
5	8	2	6	6	3	3
6	13	3	10	6	2	4
7	11	4	7	3	1	2
8	15	5	10	5	1	4
9	7	3	4	5	1	4
10	10	3	7	12	4	8
11	9	3	6	10	4	6
TOTAL	120	38	82	64	22	42
$\bar{X}$	10.9	3.45	7.45	5.82	2.00	3.82

TABLE II

ERRORS ON PRE AND POST DENSITY INVENTORY PER ITEM: NUMBERS OF TEACHERS ERRING, TOTAL NUMBER OF ERRORS, NUMBER OF DECISION ERRORS, AND NUMBER OF SUPPORT ERRORS

	PRETEST				POSTTEST			
#	TCH ERRING	TOTAL ERR	DEC ERR	SUPP ERR	TCH ERRING	TOTAL ERR	DEC ERR	SUP ERR
1	8	14	6	8	3	3	1	2
2	7	8	2	6	2	2	0	2
3	10	17	7	10	5	6	1	5
4	7	7	1	6	2	3	1	2
5	10	18	8	10	7	11	5	6
6	10	10	0	10	3	3	1	2
7	7	13	6	7	6	12	6	6
8	8	11	3	8	7	8	1	7
9	5	5	0	5	3	4	2	2
10	6	7	2	5	4	6	2	4
11	7	7	7		4	4	4	
12	6	6	6		4	4	4	
13	7	10	3	7	5	6	2	4
TOT	98	133	51	82	55	72	30	42
$\bar{X}$	7.54	12.1	3.92	7.45	4.23	6.55	2.31	3.82

TABLE III
ERROR PATTERNS ON DENSITY INVENTORY ITEMS

ITEM:	ERROR PATTERN:
1	Pre to post-test - generally corrected decision and support errors; indicates gain in understanding of mass of solid objects when they are balanced
2	Pre to post-test - generally corrected support errors; very few decision errors, totally eliminated on post-test; indicates gain in understanding of mass of solid objects when they are balanced
3	Pre to post-test - generally corrected decision errors; 4 out of 5 teachers selected 'D' support on post-test; indicates confusion of mass and density in unbalanced situation
4	Pre to post-test - generally corrected support errors; only one decision error on pre-test; indicates understanding of density of solid objects in unbalanced situation
5	7 teachers made total of 11 errors on post-test; indicates lack of understanding of mass of liquid in balanced situation
6	Pre to post-test - generally corrected errors; indicates understanding of mass of liquid in balanced situation

7	3 teachers corrected errors and 3 teachers 'learned errors' from pre to post-test; indicates confusion in some teachers about mass of gases
8	Pre to post-test - maintained or adopted incorrect 'D' support which is reasonable but not correct; indicates some confusion of mass and density of gases
9	No specific pattern although 2 teachers made correct decision on pre-test and incorrect decision on pos -test, indicating problems with mass of gases
10	Pre to post-test - new support errors appeared in post-test for 4 teachers; indicates problem with density of gases
11 & 12	Half of those teachers who erred on the pre-test erred on the post-test; indicates problems with density calculations
13	Some errors corrected but item remains troublesome